APPENDIX D
AIR MODELLING REPORT

RAMBOLL

MEMO

Job	**Emissions and Air Quality Impact Assessment from Process Stacks' and Flare Sources at Proposed Waste-to-Energy Facility in Nova Scotia**
Client	**Strum**
Date	**June 22, 2018**
To	**Shawn Duncan**
From	**Rakesh Singh and Biljana Cosic**

1. Introduction

This memorandum summarizes the methodology and results of an Air Quality Assessment carried out to evaluate the air emissions and resulting air quality impacts from combustion sources at a proposed waste-to-energy facility in Municipality of the District of Chester, Nova Scotia (the Project). The facility will produce liquid fuel by pyrolysis of waste plastics. The pyrolysis process will be a closed loop system with three reactors enclosed in a building. The main/key sources of emissions will be associated with combustion sources that will burn fuel to heat the three reactors. The primary source of fuel will be the non-condensable gas, a by-product from the process which will be used during steady-state operation. During start-up and shut-down the main system burners will be fuelled by propane which will be stored at the site. The combustion effluents will be released into the air via three stacks associated with three reactors. The process will also have a flare which will be used to burn any waste or excess non-condensable gas.

In addition to the process stack(s) and flare emissions, there will be other activities and sources at the Project site such as a cooling tower, storage tanks, material handling operation, hauling which will generate fugitive emissions. The scope of work presented in this memo is limited to the assessment of emissions from the three process stacks and flare and how the predicted (modelled) impacts compare to the Nova Scotia Air Quality Regulations Schedule A: Maximum Permissible Level Concentrations. The technical approach and key findings from the assessment are summarized in the following sections.

2. Technical Approach

Nova Scotia Air Quality Regulations do not provide specific guidance on the development of air emissions and preferred air dispersion modelling approach. In preparation of this assessment Ramboll followed guidance from other regulatory agencies in the United States and Canada such as the U.S. Environmental Protection Agency (US EPA), Ontario Ministry of the Environment and Climate Change (MOECC).

2.1 Emission Estimates

Emissions from the Project sources were estimated using the equipment design emissions provided by Strum Consulting and emission rates derived by Ramboll using published emission factors for similar processes. Table 1 shows the design and nominal emissions for a proposed design throughput of 12.5 metric tonnes per year (MT/y) and non-condensable gas fuel composition presented in Table 2. The emissions represent the total estimated release from the main system burners used to heat the three reactors (24 burners with the total rating of 6 MMBtu/hr, 8 burners per reactor) and the secondary combustion system (9.2 MMBT/hr). The emissions are representative of steady-state operations when sufficient amount of non-condensable gas is produced by the system to be used as a fuel source.

Table 1. Estimated annual emissions from process burners using non-condensable gas fuel[1]

Emissions	SO_2 (MT/y)	NO_x (MT/y)	CO (MT/y)	TSP (MT/y)	VOC (MT/y)
Design[2]	0.05	7.26	4.07	0.39	0.53
Nominal[3]	0.02	2.64	1.48	0.14	0.19

[1]Provided by Strum Consulting
[2]Based on equipment design i.e. maximum rated capacity/load
[3]Based on nominal i.e. long-term average output (nominal usage rate of about 60% is expected for the main system burners, and about 13% for the secondary combustion system)

Table 2. Non-condensable gas composition

Species	Formula	Volumetric %
Propene	C_3H_6	29.3%
Ethylene	C_2H_4	20.1%
Ethane	C_2H_6	16.3%
Methane	CH_4	18.7%
Propane	C_3H_8	6.9%
Pentane	C_5H_{12}	5.1%
n-Butane	C_4H_{10}	3.3%
Isobutane	C_4H_{10}	0.3%
Isopentane	C_5H_{12}	0.1%

During start-up and shut-down the main combustion system will be fed by propane and any excess non-condensable gas will be channelled to the flare with a rated heat capacity of 6.5 MMBtu/hr. Maximum load during flaring is expected to be about 5 MMBtu/hr. Flaring emissions were conservatively estimated by Ramboll using the following approach:

1. Flaring emissions for SO_2, NO_2, CO and TSP are initially assumed to be equal to the process design emissions (Table 1) given that both processes burn the same fuel and have similar heat loads.
2. Flaring emissions for SO_2, NO_2, CO, TSP and H_2S were then estimated using AP-42 emission factors[1] assuming design heat load of 6.5 MMBtu/hr; SO_2 emissions were estimated assuming that fuel (non-condensable gas) has an equivalent of 0.25 grains of H_2S per 100 scf of natural gas (equivalent on energy unit basis) and destruction efficiency of 98%. The assumed H_2S concentration represents a limit above which natural gas is considered "sour".[2] It represents a conservative estimate since the fuel is produced from refined plastics with no sulphur content.
3. The two emissions estimates (1 and 2) were compared for each species and the higher of the two was retained and modelled.

Emissions from process stacks during start-up and shut down periods when burner are fuelled by propane are expected to be comparable to those when burning non-condensable gas fuel (Table 1). To verify that emissions during transitional periods will not exceed process emissions AP-42 emission factors[3] were used to estimate emissions from firing propane for the total burner design load of 6 MMBtu/hr. The estimated emissions for SO_2, NO_2, CO and TSP were lower than those presented in Table 1. Assuming H_2S content in propane is equivalent to 0.25 grains per 100 scf of natural gas, H_2S emission were estimated for process stacks and were used in modelling.

2.2 Dispersion Modelling

Modelled Source Parameters and Emission Rates

Estimated emissions were modelled conservatively assuming the 3 process stacks and the flare operate continuously and simultaneously at their maximum (design) load. Modelled NO_X emissions were also conservatively modelled assuming all as NO_2 although NO_2/NO_X in-stack ratio for these type of combustion sources is expected to be significantly lower than 1. A complete list of sources modelled and their parameters is provided in Table 3 and Table 4. A figure displaying the sources modelled and their location within the Project boundary is provided in Appendix A. Note that modelled flare stack parameters represent effective parameters derived using the U.S. EPA methodology for flare parameterization.

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[1] AP 42, Fifth Edition, Volume I Chapter 13: Miscellaneous Sources, Section 13.5 Industrial Flares, 2018

[2] AP 42, Fifth Edition, Volume I Chapter 5: Petroleum Industry Section 5.3 Natural Gas Processing, 1995

[3] AP 42, Fifth Edition, Volume I Chapter 1: External Combustion Sources Section 1.5 Liquified Petroleum Gas Combustion, 2008

Table 3. Modelled Source Parameters

Point Sources									
Source ID	Description	UTM Coordinates		Elevation	Height	Dia.	Exit Vel.	Exit Temp.	Release Type
		Easting [m]	Northing [m]	[m]	[m]	[m]	[m/s]	[K]	
S67	Process stack 67	402008.00	4952414.08	176.88	12.00	0.254	9.319	813.15	Vertical
S68	Process stack 68	402009.78	4952415.47	176.81	12.00	0.254	9.319	813.15	Vertical
S69	Process stack 69	402011.62	4952421.22	176.69	12.00	0.254	9.319	813.15	Vertical
Flare	Flare	402014.12	4952433.18	176.42	9.014	5.317	1.067	1273.00	Vertical

Table 4. Modelled Source Emission Rates

Source ID	Description	SO_2	NO_2	CO	TSP	H_2S
		[g/s]	[g/s]	[g/s]	[g/s]	[g/s]
S67	Process stack 67	5.28E-04	7.67E-02	4.30E-02	4.12E-03	6.89E-07
S68	Process stack 68	5.28E-04	7.67E-02	4.30E-02	4.12E-03	6.89E-07
S69	Process stack 69	5.28E-04	7.67E-02	4.30E-02	4.12E-03	6.89E-07
Flare	Flare	1.59E-03	2.30E-01	3.03E-01	1.61E-01	2.24E-06

The air concentrations of SO_2, NO_2, CO, TSP, and H_2S were predicted using a steady-state Gaussian plume model AERMOD. The AERMOD model is developed by the U.S. EPA, and is a preferred model for near-field (<50 km) applications, including those situations with some complex terrain. The latest AERMOD version (regulatory version 18081) was used for the assessment.

Since ozone is a secondary pollutant which is formed in ambient air in the presence of VOC and NOx precursors, therefore ozone concentrations cannot be modelled using AERMOD. Ozone concentrations were estimated using the U.S. EPA VOC/NO_X Pont Source Screening Tables (USEPA 1988)[4]. The screening procedure is used to calculate ozone increment (increase in ozone concentration above an ambient background value) as a function of short and long term nonmethane organic carbon (NMOC) and NOx emissions and their ratios.

Building downwash

Building downwash effects can influence the dispersion from point sources. Building wake effects were considered in the assessment using the U.S. EPA's Building Profile Input Program (BPIPPRM) Version 04274 to characterize buildings/structures at the Project site. Only the structures which are expected to affect plume rise and dispersion from the modelled stacks were considered. These include the processing building and the cooling tower structure. A figure showing the layout of the buildings considered in the model is included in Appendix A.

Terrain

Terrain elevations were incorporated into the modelling using version 18081 of AERMAP, AERMOD's terrain pre-processor. Terrain elevation data for the entire modelling domain were extracted from Digital Elevation Model (DEM) files with a 1 arc second (approximately 30 meter) resolution produced by the United States Geological Survey (USGS). AERMAP provides both the base elevation and a hill height scale for each receptor in the modelling analysis.

Modelled Domain and Receptors

The modelling domain is a 20 km x 20 km area centred on the facility. Within the domain, a nested grid with increasing receptor spacing was created. The following table presents the spatial distribution of the receptors used for the assessment:

[4] U.S. EPA VOC/NOx Point Source Screening Tables by Richard D. Scheffe, September 1988.

Table 5. Receptor Spacing within the Project Modelling Domain

Distance from Property Boundary	Receptor Spacing
0 meters (Property Boundary)	10 meters
0 to 200 meters	20 meters
200 to 500 meters	50 meters
500 to 1,000 meters	100 meters
1,000 to 2,000 meters	200 meters
2,000 to 5,000 meters	500 meters
5,000 to 10,000 meters	1,000 meters

All receptors and source locations were reflected in the Universal Transverse Mercator (UTM) North American Datum 1983 (NAD83), Zone 20 coordinate system. The terrain elevations and receptor grid is presented in Appendix A.

Meteorological Data

Meteorological data were processed for a 5-year period 2013-2017 using surface data from Halifax International Airport, NS (WMO ID 713950) and upper air soundings from Yarmouth, NS (WMO ID 716030). Halifax International Airport site is approximately 60 km northeast from the Project site. While there are other meteorological stations closer to the site these sites are located closer to major bodies of water that can impact wind patterns considering the proximity to coastal region. The Halifax International Airport is the nearest meteorological surface station to the Project site with similar topographical setting (inland) as well as similar elevation as the Project site. It also measures all the surface parameters required by AERMOD for dispersion calculations.

Surface characteristics (albedo, Bowen ratio and surface roughness) were selected assuming a mixed forest land use. This corresponds to the land use around the Halifax airport as well as around the Project site. Ramboll used meteorological data processed using ADJ_U* option, a regulatory option for meteorological data without stability parameters (sigma theta), per recent guidance from the USEPA. The AERMET (Version 18081) pre-processor was used to process the upper air and surface meteorological data in accordance with the current AERMOD Implementation Guide (EPA-454/B-18-004, April, 2018). The wind rose for the Halifax International Airport site for the 5-year modelling period is presented in Appendix A.

Modelling Options

Modelling was performed using regularly and default settings. Dry and wet depletion options were not employed. For compassion with the Schedule A Maximum Permissible Ground Level Concentrations limit, concentrations at all receptors were modelled at ground level (0 m flagpole). Individual contaminants were modelled using averaging periods consistent with those stated in the Schedule A.

3. Modelling Results

The highest modelled concentrations for 1-hour, 8-hour, daily average and annual average over the five model years were summarized in Table 6 and compared with the Schedule A limits. Graphic outputs (e.g. concentration contours) for all modelled contaminants and averaging periods are included in Appendix A. The predicted concentrations for all contaminants are well below the permissible limits.

Table 6. Summary of Modelled Concentrations

Contaminant	Averaging Period	Schedule A Maximum Permissible Ground Level Concentration (μg/m³)	Maximum Modelled Concentration (μg/m³)	Percent of Limit
Carbon Monoxide (CO)	1 hour	34600	48.4	0.14%
	8 hours	12700	29.7	0.23%
Hydrogen Sulfide (H_2S)	1 hour	42	7.70E-04	0.002%
	24 hours	8	3.20E-04	0.004%
Nitrogen Dioxide (NO_2)	1 hour	400	86.2	21.55%
	Annual	100	6.72	6.72%
Ozone (O_3)	1 hour	160	<21.46	<13.41%
Sulphur Dioxide (SO_2)	1 hour	900	0.594	0.07%
	24 hours	300	0.239	0.08%
	Annual	60	0.046	0.08%
Total Suspended Particulate (TSP)	24 hours	120	7.218	6.02%
	Annual	70*	1.910	2.73%

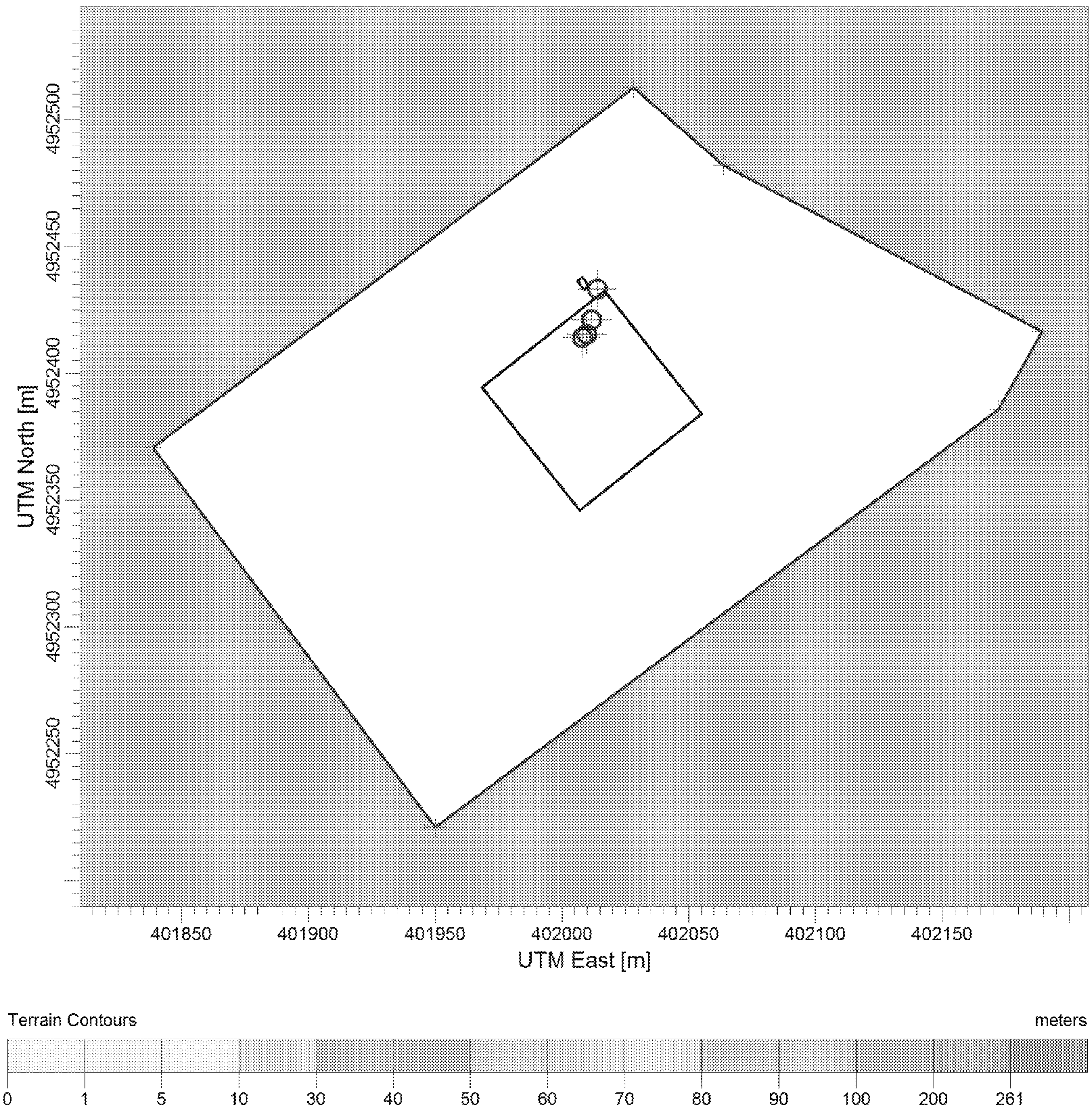
Note that the predicted concentrations are due to the process stacks and flare emissions only, they do not account for other fugitive source of emissions which may be associated with the Project. The predicted concentrations also do not include contribution of the ambient background. Note that the predicted ozone concentration is not a result of dispersion modelling. The ozone concentration was estimated from the magnitude of VOC and NOx emissions. The stack VOC and NOx emissions considered in this assessment and their ratio are well below the screening thresholds which allows determination of an upper limit only. Actual O_3 concentrations due to Project sources are expected to be considerably lower than the upper bound presented in Table 6.

4. Conclusions

The current assessment indicates that even with the conservative approach the predicted impacts due to the Project sources will be well below applicable limits in Schedule A. Although this assessment is limited to the three process stacks and the flare emissions only, these sources are expected to be among the largest sources and contributors at the Project site.

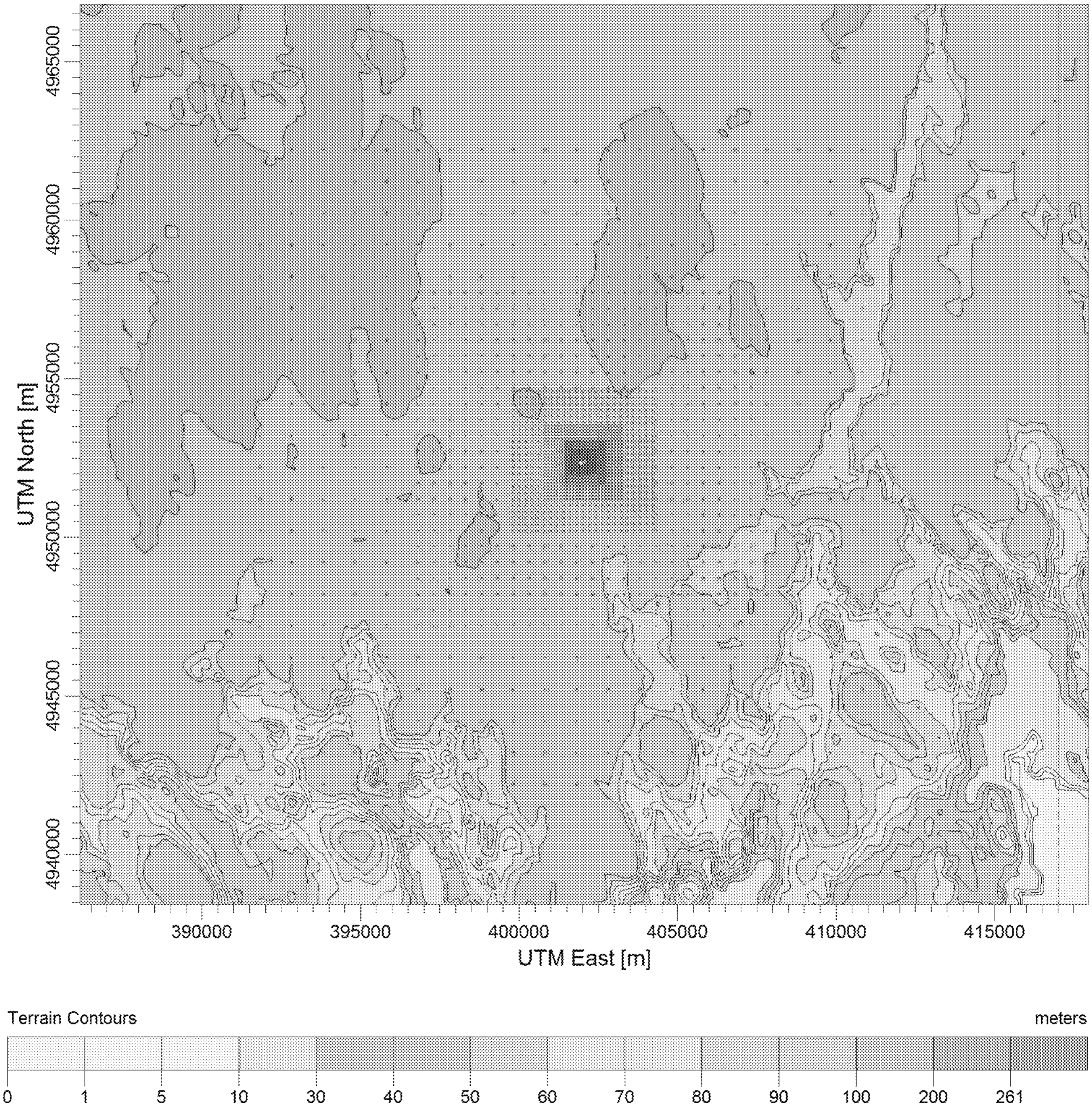
APPENDIX A

Strum Consulting
Building and Point Sources



	SOURCES: **4**	COMPANY NAME: **Ramboll**	
	RECEPTORS: **3477**	MODELER:	RAMBOLL
		SCALE: 1:2,500 0 — 0.05 km	
		2018-06-22	PROJECT NO.: **324000270**

Strum Consulting
Nested Grid Receptor Locations



	SOURCES: **4**	COMPANY NAME: **Ramboll**	
	RECEPTORS: **3477**	MODELER:	RAMBOLL
		SCALE: 1:200,000 0 ... 5 km	
		2018-06-22	PROJECT NO.: **324000270**

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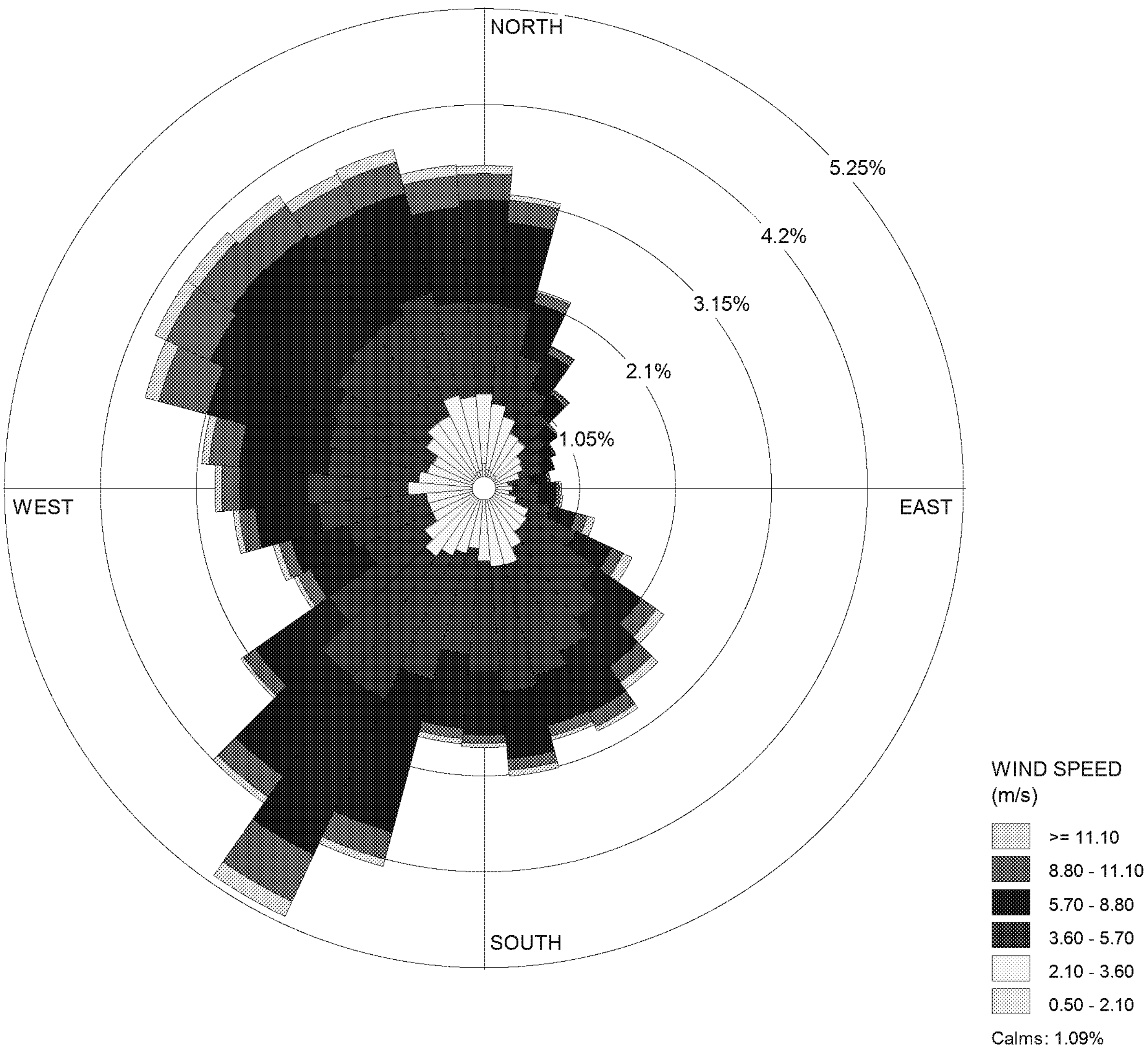
ED_005952_00000752-00012

WIND ROSE PLOT:

Strum Consulting
Halifax International Airport WMO ID 713590

DISPLAY:

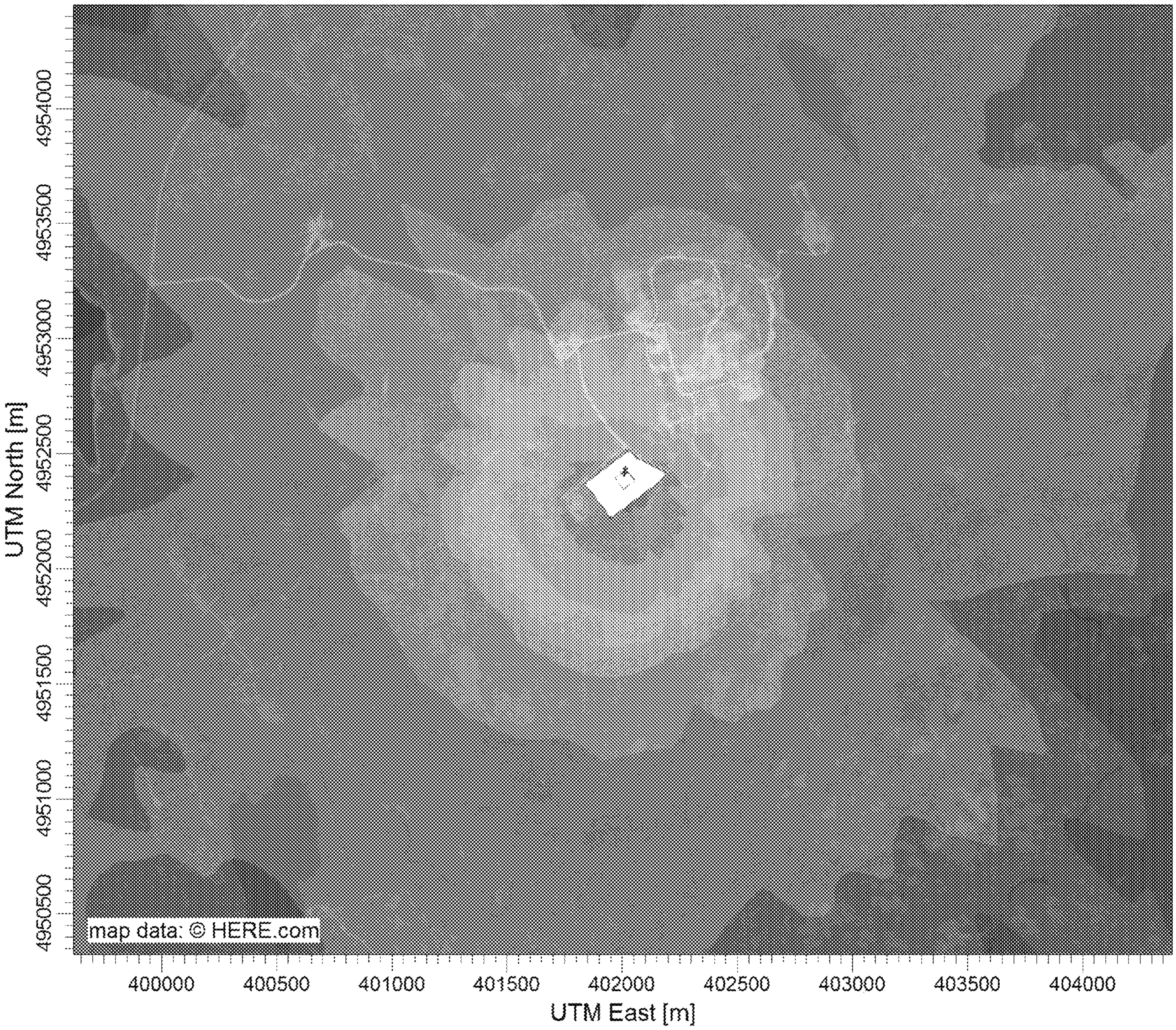
Wind Speed
Direction (blowing from)



COMMENTS:	DATA PERIOD: **Start Date: 1/1/2013 - 00:00** **End Date: 12/31/2017 - 23:59**	COMPANY NAME: **Ramboll**
		MODELER:
	CALM WINDS: **1.09%**	TOTAL COUNT: **42985 hrs.**
	AVG. WIND SPEED: **5.12 m/s**	DATE: **6/22/2018**
		PROJECT NO.: **324000270**

WRPLOT View - Lakes Environmental Software

Strum Consulting
Peak 1-Hr Average Carbon Monoxide Concentration Contour



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL — ug/m^3

Max: 48.36 [ug/m^3] at (402076.98, 4952315.19)

0.48 | 0.50 | 0.60 | 0.80 | 1.00 | 2.00 | 4.00 | 5.00 | 6.00 | 8.00 | 10.00 | 20.00 | 40.00 | 48.36

	SOURCES: 4	COMPANY NAME: Ramboll	
	RECEPTORS: 3477	MODELER:	RAMBOLL
	Concentration	SCALE: 1:30,000 (0 — 1 km)	
	MAX: 48.36 ug/m^3	2018-06-22	PROJECT NO.: 324000270

AERMOD View - Lakes Environmental Software

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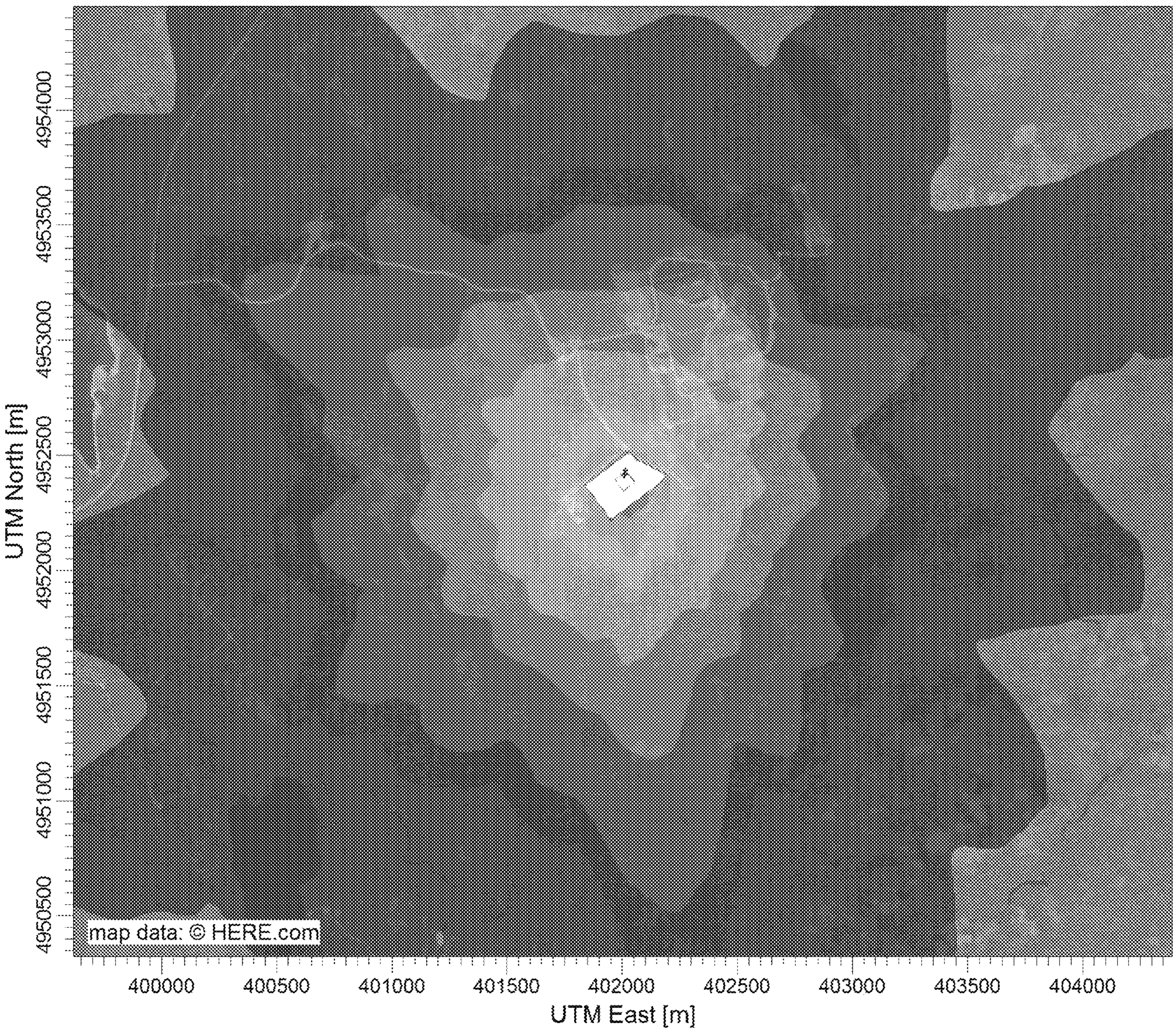
Strum Consulting
Peak 8-Hr Average Carbon Monoxide Concentration Contour



PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 29.7 [ug/m^3] at (402069.05, 4952309.31)

0.3 0.5 0.6 1.0 2.0 5.0 6.0 10.0 20.0 29.7

	SOURCES: **4**	COMPANY NAME: **Ramboll**	
	RECEPTORS: **3477**	MODELER:	RAMBOLL
	Concentration	SCALE: 1:30,000 0 1 km	
	MAX: **29.7 ug/m^3**	**2018-06-22**	PROJECT NO.: **324000270**

AERMOD View - Lakes Environmental Software

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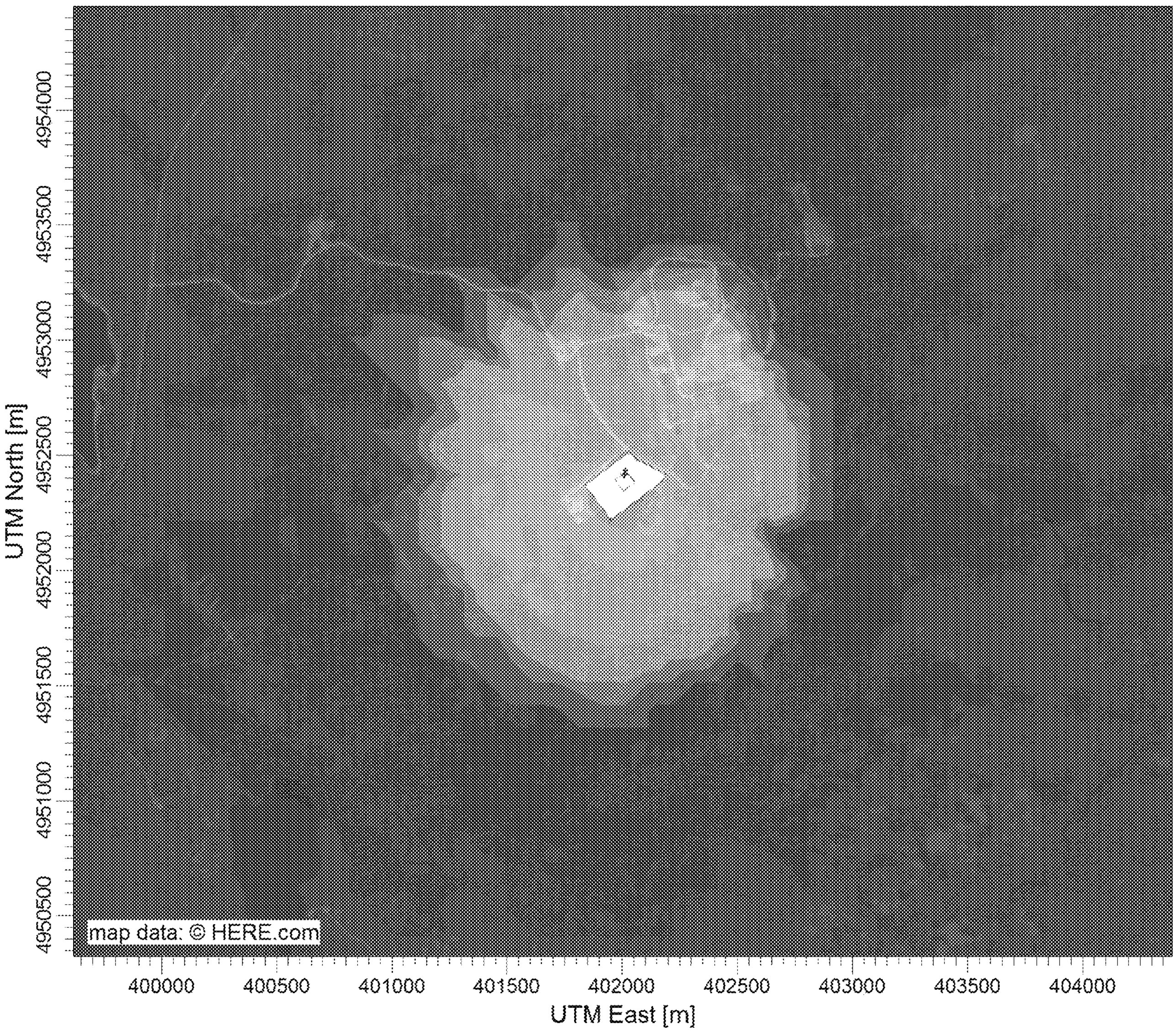
Strum Consulting
Peak 1-Hr Average Hydrogen Sulphide Concentration Contour



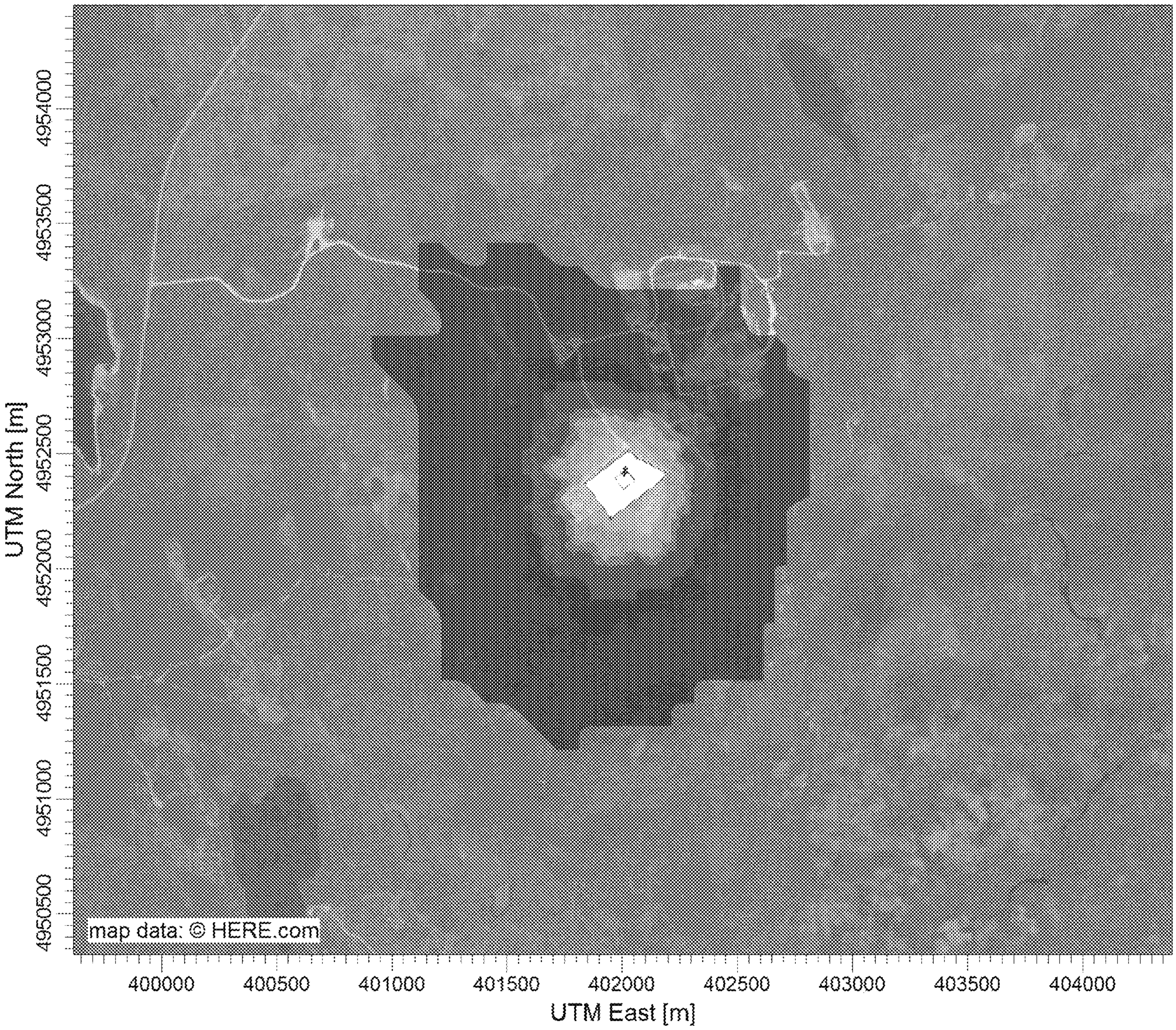
PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

Max: 7.7E-04 [ug/m^3] at (402076.98, 4952315.19)

1.0E-05 2.0E-05 4.0E-05 5.0E-05 6.0E-05 1.0E-04 3.0E-04 5.0E-04 7.0E-04 7.7E-04

	SOURCES: **4**	COMPANY NAME: **Ramboll**	
	RECEPTORS: **3477**	MODELER:	RAMBOLL
	Concentration	SCALE: 1:30,000 0 — 1 km	
	MAX: **7.7E-04 ug/m^3**	**2018-06-22**	PROJECT NO.: **324000270**

Strum Consulting
Peak 24-Hr Average Hydrogen Sulphide Concentration Contour



PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL

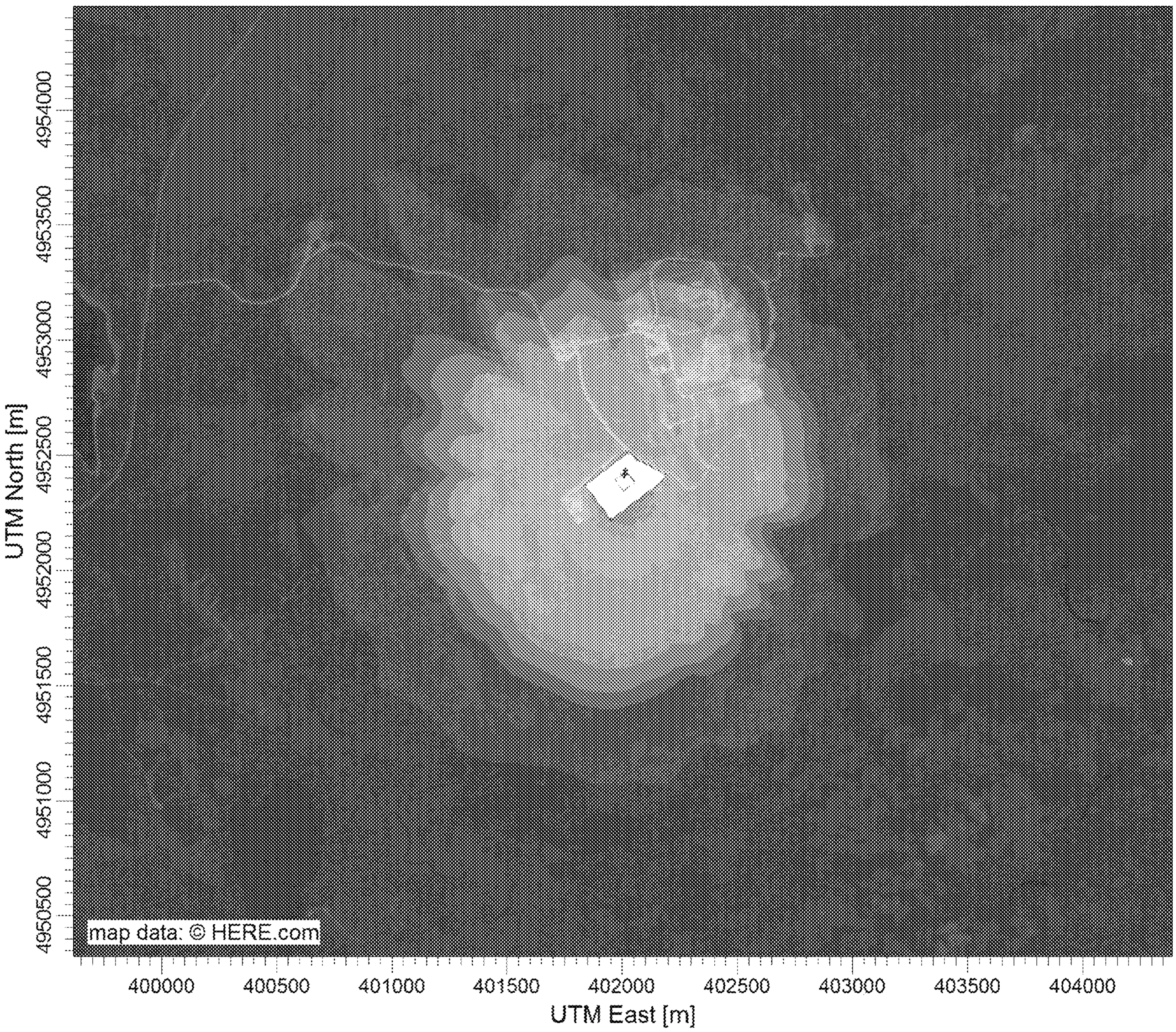
ug/m^3

Max: 3.2E-04 [ug/m^3]

1.0E-05 2.0E-05 3.0E-05 5.0E-05 6.0E-05 9.0E-05 1.0E-04 2.0E-04 3.0E-04 3.2E-04

SOURCES: **4**	COMPANY NAME: **Ramboll**	
RECEPTORS: **3477**	MODELER:	RAMBOLL
Concentration	SCALE: 1:30,000 0 — 1 km	
MAX: **3.2E-04 ug/m^3**	**2018-06-22**	PROJECT NO.: **324000270**

Strum Consulting
Peak 1-Hr Average Nitrogen Dioxide Concentration Contour



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL | ug/m^3

Max: 86.2 [ug/m^3] at (402076.98, 4952315.19)

0.9 | 1.0 | 3.0 | 5.0 | 6.0 | 8.0 | 10.0 | 30.0 | 50.0 | 60.0 | 80.0 | 86.2

	SOURCES: **4**	COMPANY NAME: **Ramboll**	
	RECEPTORS: **3477**	MODELER:	RAMBOLL
	Concentration	SCALE: 1:30,000 0 — 1 km	
	MAX: **86.2 ug/m^3**	**2018-06-22**	PROJECT NO.: **324000270**

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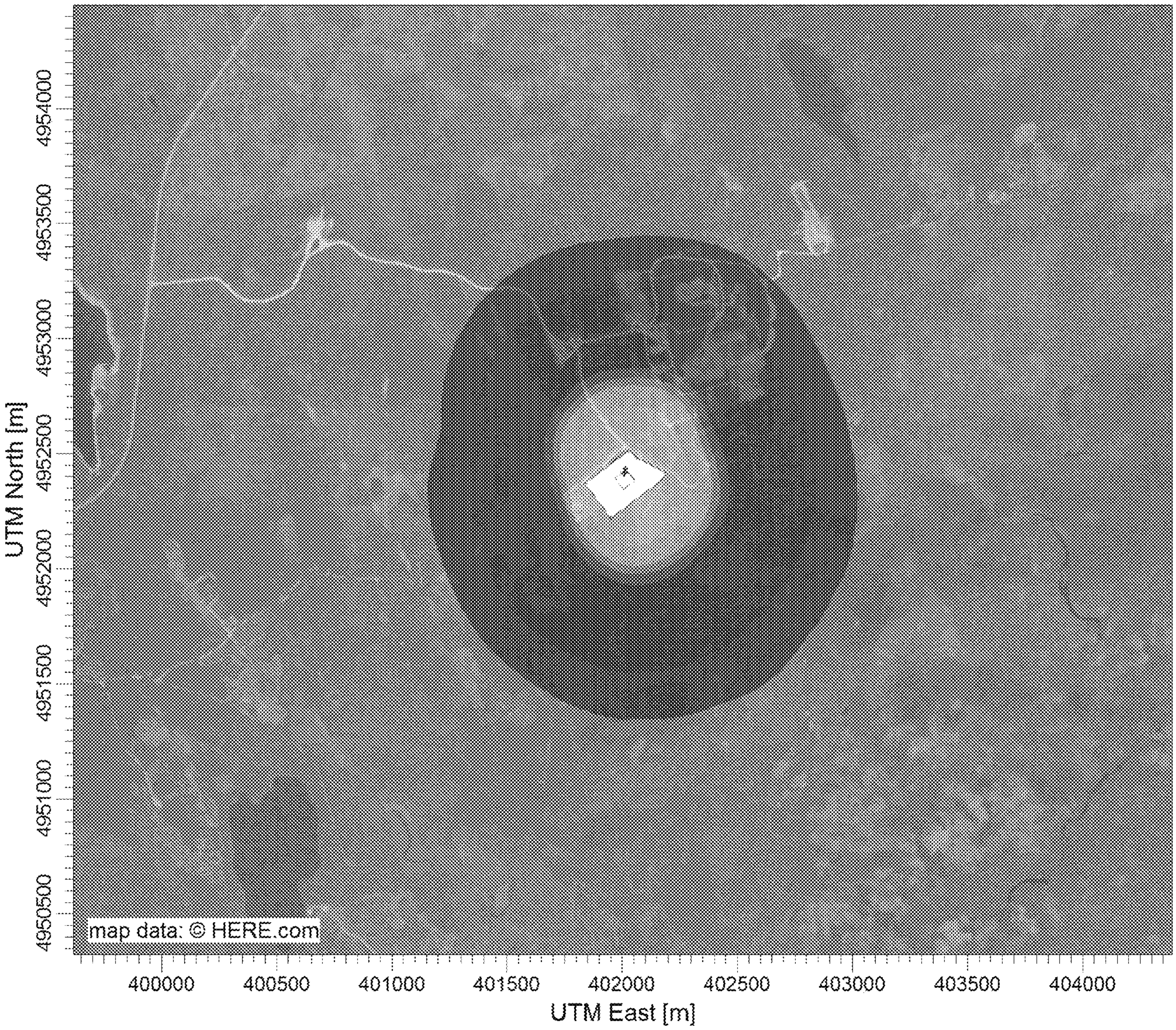
Strum Consulting
Peak Annual Average Nitrogen Dioxide Concentration Contour



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

ug/m^3

Max: 6.72 [ug/m^3] at (401980.88, 4952477.12)

0.06 0.10 0.40 0.50 0.60 1.00 4.00 5.00 6.00 6.45

SOURCES: **4**	COMPANY NAME: **Ramboll**		
RECEPTORS: **3477**	MODELER:		RAMBOLL
Concentration	SCALE: 1:30,000 0 — 1 km		
MAX: **6.72 ug/m^3**	**2018-06-22**	PROJECT NO.: **324000270**	

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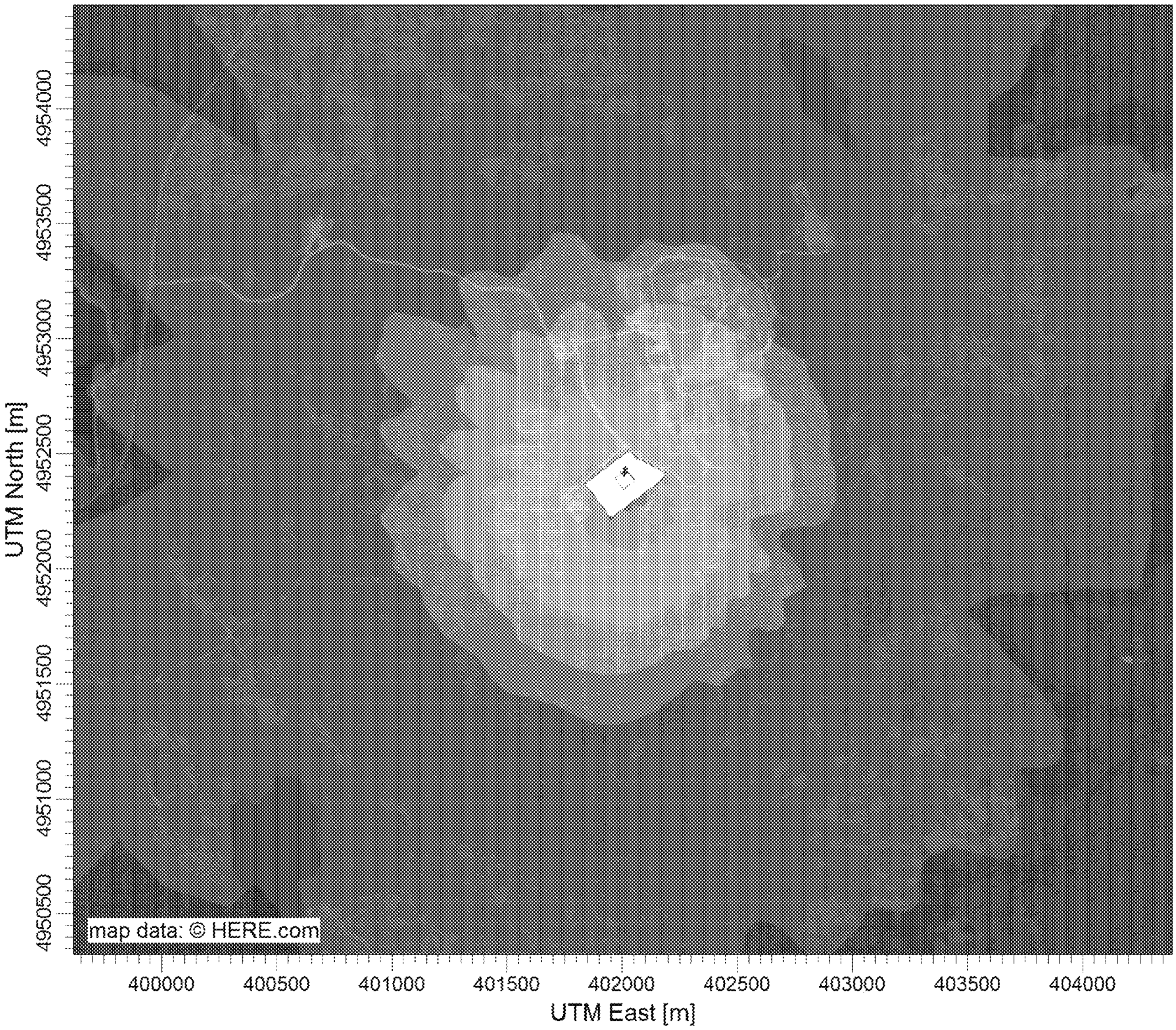
Strum Consulting
Peak 1-Hr Average Sulphur Dioxide Concentration Contour



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL   ug/m^3

Max: 0.594 [ug/m^3] at (402076.98, 4952315.19)

0.006 0.009 0.010 0.030 0.050 0.090 0.100 0.300 0.500 0.594

	SOURCES: **4**	COMPANY NAME: **Ramboll**	
	RECEPTORS: **3477**	MODELER:	RAMBOLL
	Concentration	SCALE: 1:30,000 (0 — 1 km)	
	MAX: **0.594 ug/m^3**	**2018-06-22**	PROJECT NO.: **324000270**

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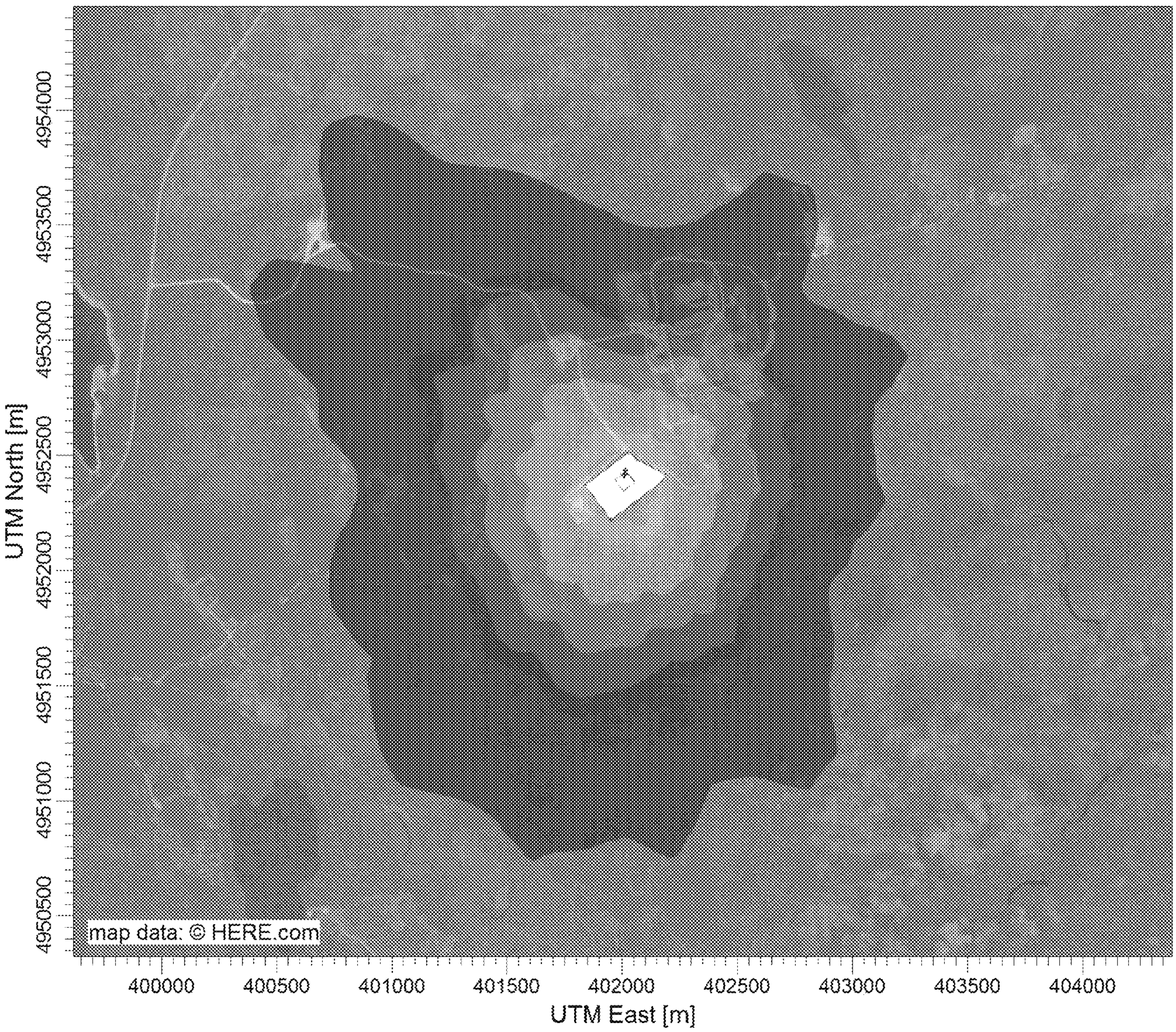
Strum Consulting
Peak 24-Hr Average Sulphur Dioxide Concentration Contour



PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 0.239 [ug/m^3] at (402053.20, 4952297.56)

0.002 0.005 0.006 0.010 0.020 0.050 0.060 0.100 0.200 0.239

	SOURCES: 4	COMPANY NAME: **Ramboll**	
	RECEPTORS: **3477**	MODELER:	RAMBOLL
	Concentration	SCALE: 1:30,000 0 — 1 km	
	MAX: **0.239 ug/m^3**	**2018-06-22**	PROJECT NO.: **324000270**

AERMOD View - Lakes Environmental Software

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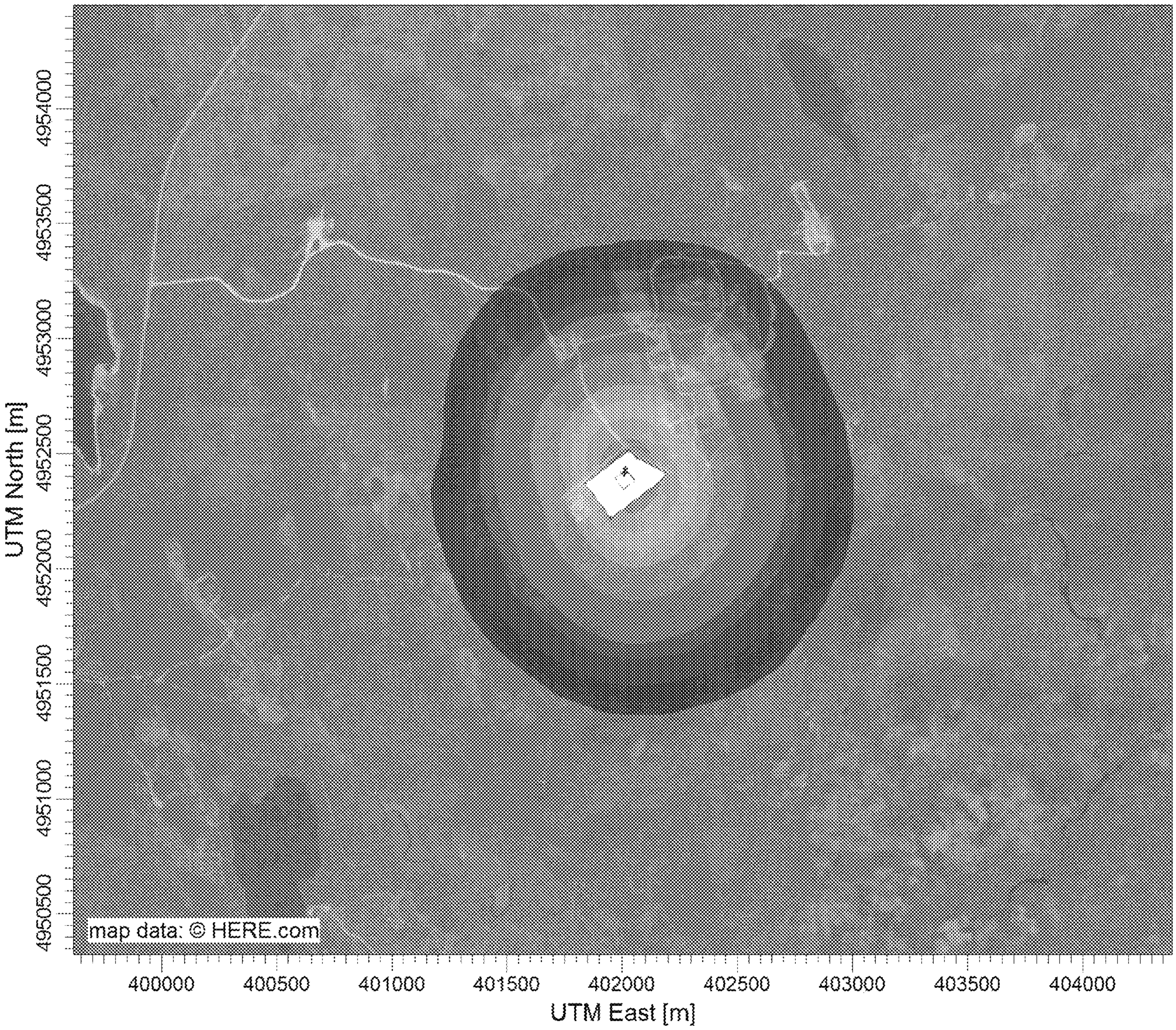
Strum Consulting
Peak Annual Average Sulphur Dioxide Concentration Contour



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL ug/m^3

Max: 4.6E-02 [ug/m^3] at (401980.88, 4952477.12)

4.6E-04 5.0E-04 6.0E-04 8.0E-04 1.0E-03 2.0E-03 4.0E-03 5.0E-03 6.0E-03 8.0E-03 1.0E-02 2.0E-02 4.0E-02 4.6E-02

	SOURCES: 4	COMPANY NAME: Ramboll	
	RECEPTORS: 3477	MODELER:	RAMBOLL
	Concentration	SCALE: 1:30,000 0 — 1 km	
	MAX: 4.6E-02 ug/m^3	2018-06-22	PROJECT NO.: 324000270

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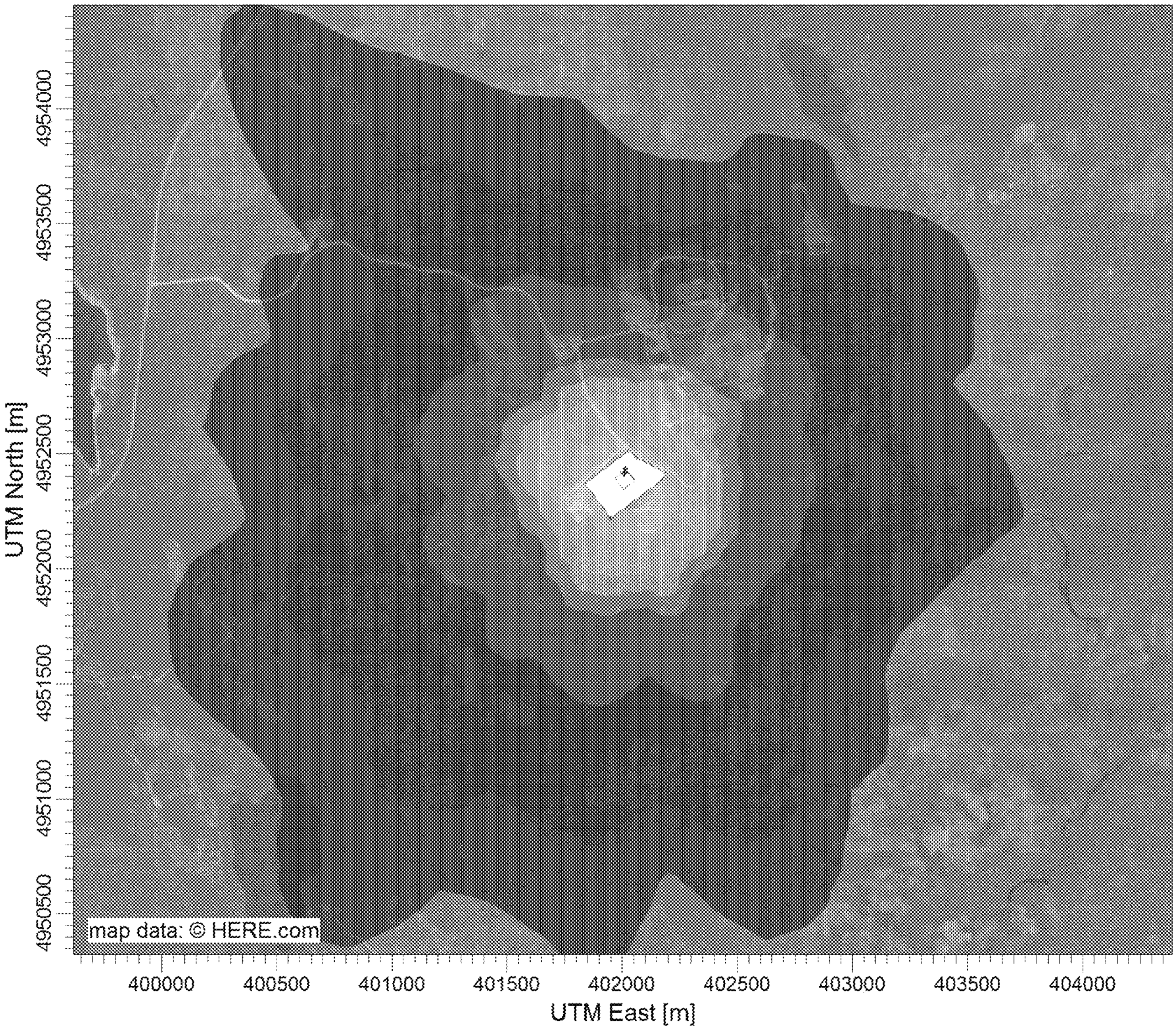
Strum Consulting
Peak 24-Hr Average Total Suspended Particulate Concentration Contour



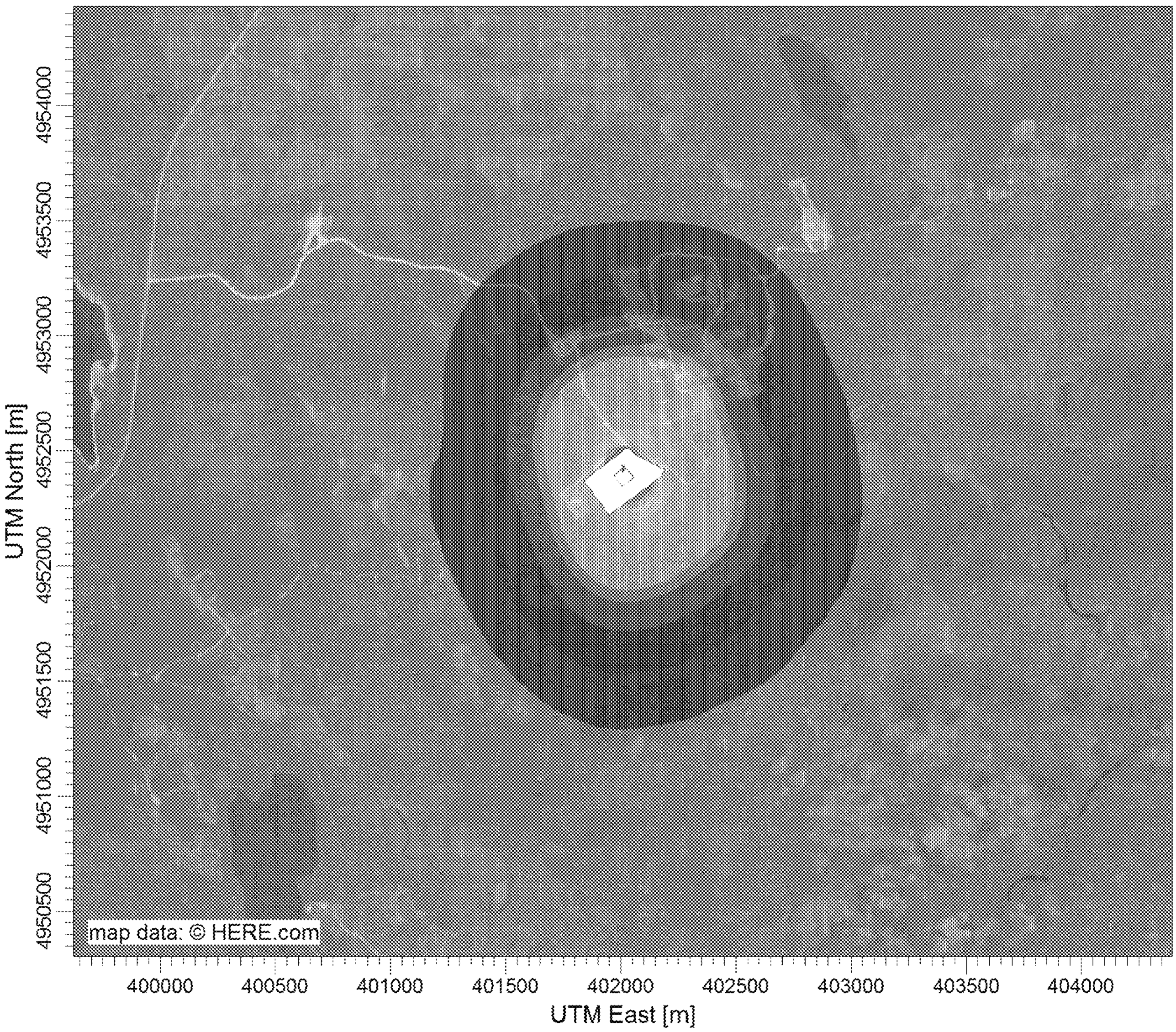
PLOT FILE OF HIGH 1ST HIGH 24-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

Max: 7.22 [ug/m^3] at (402069.05, 4952309.31)

0.07 0.10 0.20 0.50 0.70 1.00 2.00 5.00 7.00 7.22

SOURCES: 4	COMPANY NAME: Ramboll	
RECEPTORS: 3477	MODELER:	RAMBOLL
Concentration	SCALE: 1:30,000 0 — 1 km	
MAX: 7.22 ug/m^3	2018-06-22	PROJECT NO.: **324000270**

Strum Consulting
Peak Annual Average Total Suspended Particulate Concentration Contour



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL — ug/m^3

Max: 1.91 [ug/m^3] at (401980.88, 4952477.12)

0.02 | 0.03 | 0.05 | 0.08 | 0.10 | 0.30 | 0.50 | 0.80 | 1.00 | 1.91

	SOURCES: **4**	COMPANY NAME: **Ramboll**	
	RECEPTORS: **3477**	MODELER:	RAMBOLL
	Concentration	SCALE: 1:30,000 (0 — 1 km)	
	MAX: **1.91 ug/m^3**	**2018-06-22**	PROJECT NO.: **324000270**

AERMOD View - Lakes Environmental Software

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